Microreactors for Catalyst Testing

Personnel
S. Ajmera, C. Delattre, C. Baertsch, K. Jensen, and M. Schmidt

Sponsorship
MIT MicroChemical Systems Technology Center

We are exploring the use of microfabricated chemical reactors for the improved testing of heterogeneous gas phase catalytic processes. In order that results from the microreactor are relevant to macroscale processes, we are designing microfabricated packed-bed reactors that utilize standard catalyst particles. Through the use of novel flow geometries and fluid distribution mechanisms directly integrated into the reactor design, we have designed a silicon cross-flow micro packed-bed reactor that approaches a gradientless reactor for quantitative kinetics determination. The cross-flow reactor (Figure 41) achieves uniform flow distribution over a wide (25.5 mm) but shallow (400 mm long ¥ 500 mm deep) catalyst bed to realize differential conversions with sufficient reaction to allow monitoring with conventional analysis techniques. A set of shallow microfabricated channels maintains a spatially uniform pressure drop irrespective of variations in catalyst packing. Experiments and finite element simulations confirm the bed is isobaric with even distribution of flow and a pressure drop ~1600x smaller than traditional micro packed-bed designs. Quantitative analysis of transport effects indicates that the microreactor length scale suppresses thermal and mass gradients in the catalyst bed. These characteristics make the cross-flow microreactor a superior tool to obtain kinetics and optimize reaction conditions. Experiments with CO oxidation and acetylene hydrogenation confirm the ability of the microreactor to obtain quantitative and accurate information such as turnover frequency (activity), reaction order (mechanistic), selectivity, activation energy, and deactivation that compares well with parameters previously determined in macro-scale systems. Reactor modeling indicates that the catalyst bed operates differentially even at total conversions that would be considered large in traditional reactors adding to the utility of the cross-flow microreactor as an efficient laboratory tool.

In addition to micro packed-bed reactors, we are developing techniques to characterize catalyst properties such as surface area and perform chemical analysis in-situ providing a fully functional chemical reactor/analysis tool for catalyst testing. Research is also currently under way to develop robust high temperature/high pressure fluidic interconnects. This technology will allow the operation of multiple reactors in parallel which will enable multi-reactor high-throughput quantitative catalyst testing as well as the development of mini-chemical plants for chemical production utilizing multi-step synthesis.

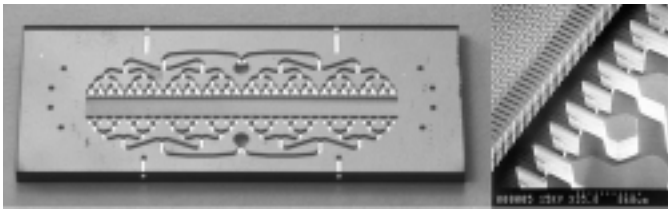

Fig. 41: Photograph of cross-flow microreactor for catalyst testing (Felice Frankel) and electron micrograph of catalyst channel detail.